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Late-Glacial vegetation and climate changes in mountain areas as inferred from pollen data : the high-resolution record of the Lauza peat bog (Champsaur, southern French Alps).

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Pollen data represent the most widely available quantitative record of past climates and are an efficient tool for the reconstruction of vegetation and its responses to abrupt climate changes. Palynology is thus the most common tool for Quaternary palaeoecology and palaeoclimate reconstructions. Transfer-functions are now often used for the reconstructions of past climate from pollen sequences. However, the application of these current methods on mountainous pollen sites still yields unreliable results and quantitative estimates of the climate from mountainous records are still rare, especially for the Late-Glacial, which is generally poorly recorded in these areas due to elevation. Mountainous vegetation has been yet shown to be particularly sensitive to climate changes and is prized as sources of high biodiversity. Climate variations have had a particularly strong effect on mountainous ecosystems and mountainous pollen sequences therefore represent ideal archives for the study of past climate change. The difficulties in reconstructing vegetation, and thus climate, history from palynological records in mountain areas have long been known. Several possible causes may be involved in the problems encountered: the lack of modern samples from mountainous areas in the modern pollen databases, wind-driven uphill transport of tree pollen into the high-elevated zones or as the result of the complexity of mountainous ecosystems, from which complex relationships exist between vegetation belts and relative pollen

percentages depending on local physiographic conditions. This phenomena become more important when the arboreal cover decreases, as closed tree formations have a filtering action on non-local pollen transported by wind, decreasing relative percentages.

The purpose of this study is to obtain robust and precise quantitative estimates of the Late-Glacial and early Holocene climate of alpine region from a high-resolution pollen record taken from the long sequence of the Lauza, French Alps. Our objective is to examine the palynological and magnetic susceptibility records, which cover the whole Late-Glacial and the Holocene, in particular considering the palaeovegetation record that they provide, and their palaeoclimatic interpretation. We decided to focus on Late-Glacial period since the study of previous palynological data and ice-cores has shown that the transition from the last glacial period to the present interglacial was a period of special “climatic” interest characterized by alternating cold and warm intervals with rapid transitions.

Lauza peat bog is a mid-altitude small palaeolake located near the Drac River at 1140 m a.s.l. in the lower Montane belt of the Champsaur Valley (southern French Alps). Sediment cores were taken at three different places in the former lake basin. Core 1, which was subsequently used for the multi-proxy study, was extracted from the deepest part ca. in the centre of the present peat bog, and is more than 7 m long, 3.5 m of these belonging to the Late-Glacial. This sequence thus provides an exceptional sedimentation rate considering the mountainous environment, especially for the Late-Glacial and early Holocene periods, offering a great opportunity to study precisely rapid climate changes and vegetation responses. The main vegetation changes in the past are recorded at the site, especially by distinguishing differences between the local, extra-local and regional vegetation covers. The Late-Glacial vegetation changes are well established, clearly characterized by several cyclic transitions from open vegetation with steppe elements to more or less forested landscapes.

High-temporal resolution analyses of pollen record from Lauza peat bog provide multi-proxy, quantitative estimates of climatic change during the Late-Glacial period in southern French Alps. Past temperature and moisture parameters are estimated using several methods of transfer-functions for the longer pollen record (core 1). The standard "modern analogue technique" (MAT), constrained or not by biomes, and "Plant Functional Types" (PFTs) methods are applied to the pollen sequence to provide quantitative estimates of the Late-Glacial and the early Holocene climate. The Biome constraint is used to limit the effect of pollen blowing uphill by wind on pollen-based climate reconstruction. To improve the reconstruction of the Late-Glacial climate for our mountainous site, we have used a new modern pollen database updated by the addition of samples from the Tibetan plateau cold steppes (118), Scandes Mountain pioneer vegetation (37), Spain (17), but also new high-altitude pollen samples (90) which have been collected from different vegetation belts in the Alps. This new added sample collection focuses on areas that are characterized by natural or pseudo-natural vegetation, reflecting climate conditions. Furthermore, the modern analogues that appeared unreliable, due to anthropogenic modification of the landscape have been removed.

The palaeoclimate parameters inferred from pollen data using the MAT and PFT methods, are mean temperature of the coldest month (Tco), mean temperature of the warmest month (Twa), average annual temperature (Tann), annual precipitation (Pann), and actual over potential evapotranspiration (E/PE). The evolution of each reconstructed climatic parameter is expressed by a curve, displayed on a stratigraphic and chronological scale. The different curves obtained for the Lauza sequence show consistent trends for climate parameters. By using the results from the different methods, the magnetic susceptibility, and the oxygen isotope ratios from the Greenland ice records as an additional palaeoclimate reference, it is possible to establish a general scheme of climatic variations at Lauza peat bog. Major abrupt changes associated with the Oldest Dryas/Bölling, Alleröd/Younger Dryas, and the Youger Dryas/Preboreal transitions are quantified as well as other minor fluctuations related to the cold events (e.g., Preboreal oscillation).

The comparison of the different methods applied shows that they provide generally similar climate signals, with some exceptions. The study also shows the effectiveness of combining several reconstruction methods, increasing the confidence in the data, and thus obtaining more precise and robust climate estimates. Finally, our results are compared with recent studies carried out on high-altitude pollen sites in the alpine region, but also with those obtained for low- and mid-altitude sites in other European regions (e.g. Jura Mountains, Switzerland, Italy).